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WATERTOWN ARSENAL
WATERTOWN 72, MASS.

WAL TN 201/1

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WATERTOWN ARSENAL LABORATORIES

⑥ BORING MILL GEAR EXAMINED FOR METALLURGICAL DEFECTS.

⑨ TECHNICAL NOTE NO. ⑭ WAL-TN-201/1

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⑩ BY
E. L. REED

⑪ DECEMBER 1959

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Machine parts

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TITLE

BORING MILL GEAR EXAMINED FOR METALLURGICAL DEFECTS

ABSTRACT

A 3-inch G & L gear for a horizontal boring mill, having two broken teeth, was examined at the request of Mr. F. L. Dolan, Arsenal Operations Division. It was found that the gear and shaft were one integral unit machined from barstock and that the shaft contained a number of fine longitudinal hairline cracks. Undercuts due to machining were found at the base of the broken teeth. The macrostructure was typical of barstock.

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Metallurgist

APPROVED:

J. F. Sullivan
J. F. SULLIVAN
Director
Watertown Arsenal Laboratories

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REPORT APPROVED

Date- 21 Jan 60

WAL Board of Review

Chairman- WSW

MATERIALS

A 3-inch horizontal boring mill G & L gear, WA 3351, with two broken gear teeth was submitted by Mr. F. L. Dolan, Arsenal Operations Division, for metallurgical examination. One broken gear tooth was submitted with the boring mill gear. The gear and shaft were one unit.

Examination of Machined Surface of Broken Tooth

A noticeable machine mark or undercut was present where the root circle joins the flank of the tooth. Such a condition is a stress riser when the gear is subject to shock. Figure 1 illustrates the undercut which caused the failure of the tooth.

Zyglo Penetrant Test

The section was subjected to the Zyglo penetrant test. It was found that the shaft contained many seams and fine longitudinal hairline cracks (Figure 2). No such cracks were found in the gear.

Macrostructure

The section was cut through the longitudinal axis, blanchard ground and etched in a macro-etching solution containing 38% hydrochloric acid, 12% sulphuric acid, and 50% water heated to a temperature of 170°F. The macrostructure consists of banding or straight-grained structure, sometimes called fiber, which is typical of that found in sections machined from barstock (Figure 3).

Microstructure

Figure 4 illustrates segregated porosity present in the transverse section of the broken tooth of the gear taken from area "A" shown in Figure 2. Also many elongated nonmetallic inclusions were present in the section as shown in Figure 5. The microstructure of the broken tooth consists of segregated areas containing some ferrite tempered high temperature bainite and tempered martensite as shown in Figure 6. The presence of ferrite and tempered high temperature bainite is not desirable in a heat-treated unit subjected to fatigue or shock. On the other hand such a unit heat treated to 100% tempered martensite is most desirable.

A fine grain size, ASTM 9-10 was found in the gear; also, the hardness of the broken tooth was Rockwell C52.

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RESULTS AND DISCUSSION

Results of Investigation

1. The failure of the broken gear tooth was due to an undercut where the root circle joins the flank of the tooth.
2. Many fine longitudinal cracks were detected on the shaft by the Zygo Penetrant Method.
3. The unit was machined from barstock containing segregated impurities resulting in an unsatisfactory distribution of fiber in the gear section.
4. The heat treatment given the unit was not adequate to obtain a satisfactory microstructure.

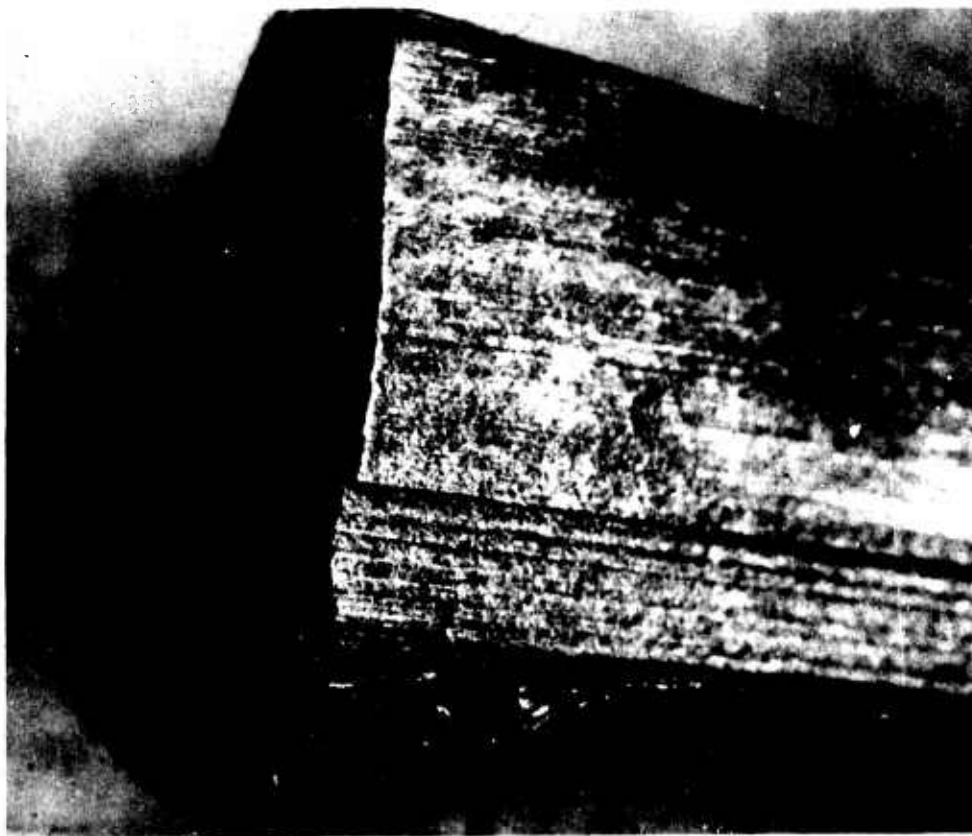
Discussion

Undercutting at the base of one of the gear teeth is responsible for rupture of the tooth.

In the gear section examined which was machined from barstock, the fiber produces a straight-grained structure. When fiber is parallel to the pitch line of the tooth and parallel to the direction of applied stress, this tooth will be greatly inferior to a properly forged upset gear section where the grain of steel flows radially and the direction of applied stress is perpendicular to the direction of fiber.

Since the boring mill gear contained pronounced segregations of non-metallic inclusions and porosity, it is believed the section was machined from a central portion of dirty barstock. Undoubtedly, the fine hairline cracks found on the surface of the shaft are connected with the elongated nonmetallic stringers present in the steel.

The heat treatment given the section was not adequate to obtain a desirable microstructure of tempered martensite.

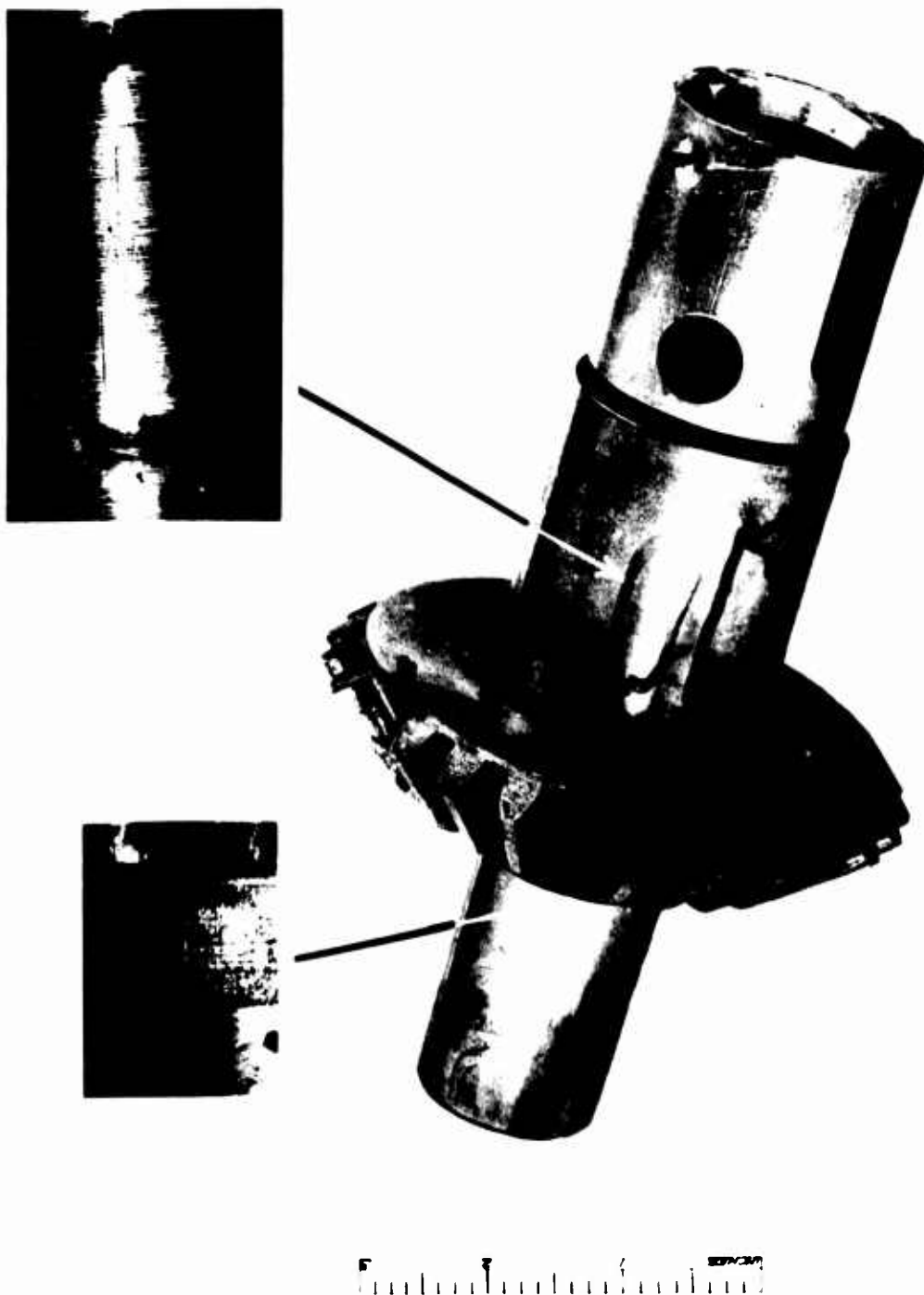


X10

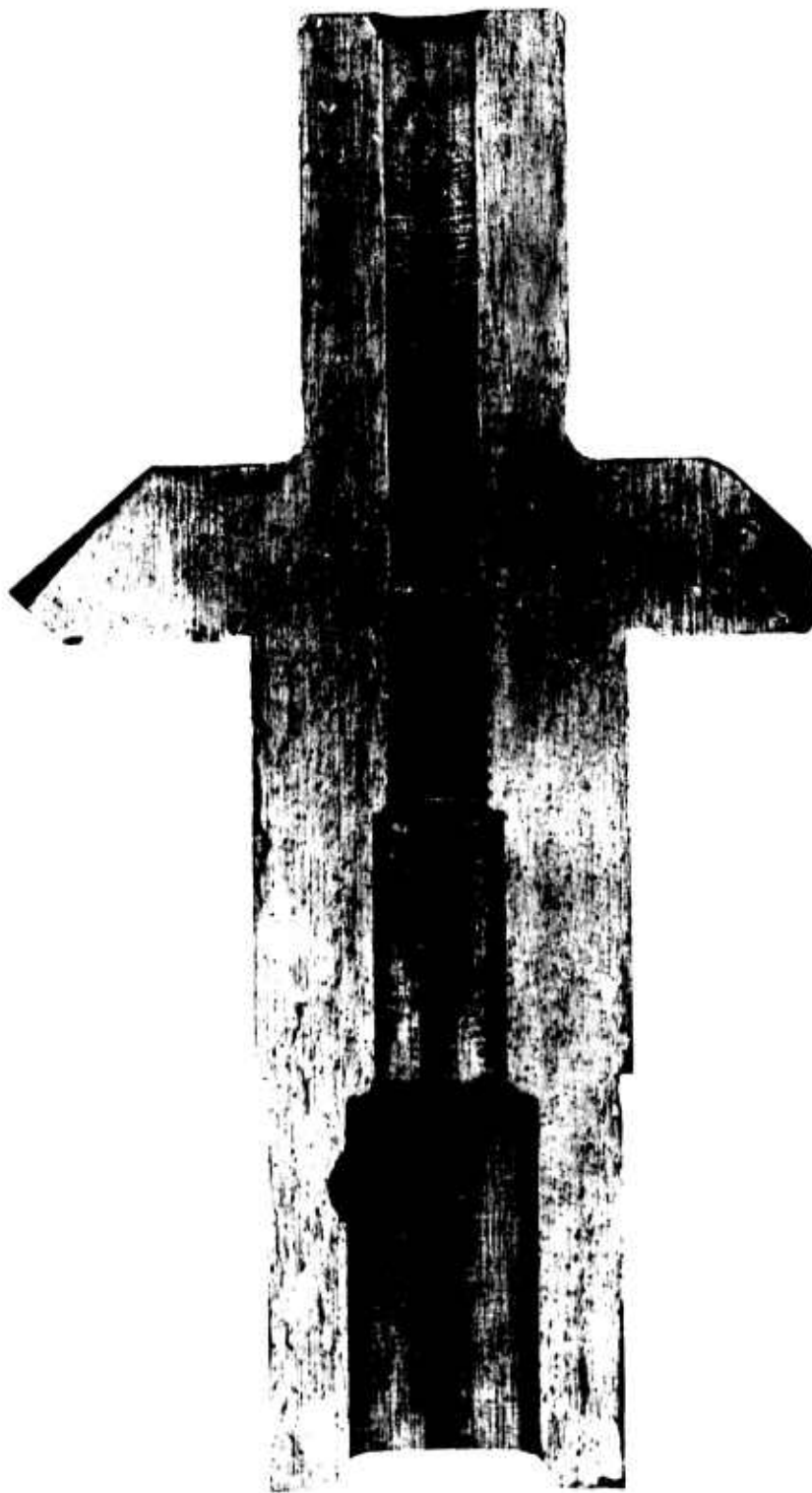
BROKEN TOOTH AT "A" SHOWN IN FIGURE 2. DEEP UNDERCUT IS SHOWN WHERE
ROOT CIRCLE JOINS FACE FLANK OF TOOTH. NOTE ARROW SHOWING ORIGIN OF
FAILURE.

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FIGURE 1



DEFECTIVE 3" HORIZONTAL BORING MILL G&L GEAR, WA 3351. TWO TEETH ARE MISSING ON THE GEAR (SEE "A" AND "B"). TYPICAL FINE LONGITUDINAL CRACKS ON THE SHAFT ARE REVEALED BY ZYGLO PENETRANT TEST.



MACROSTRUCTURE OF LONGITUDINAL SECTION OF GEAR AND SHAFT. THIS SECTION WAS IMPROPERLY MADE AS IT WAS MACHINED FROM BARSTOCK RESULTING IN AN UNSATISFACTORY DISTRIBUTION OF FIBER, THAT IS, A STRAIGHT-GRAINED STRUCTURE. SECTION IS CUT THROUGH THE BASE OF BROKEN TOOTH "A" (FIGURE 2).

**MICROSTRUCTURE OF TRANSVERSE SECTION OF
BROKEN TOOTH ON GEAR (SEE "A", FIGURE 2)**

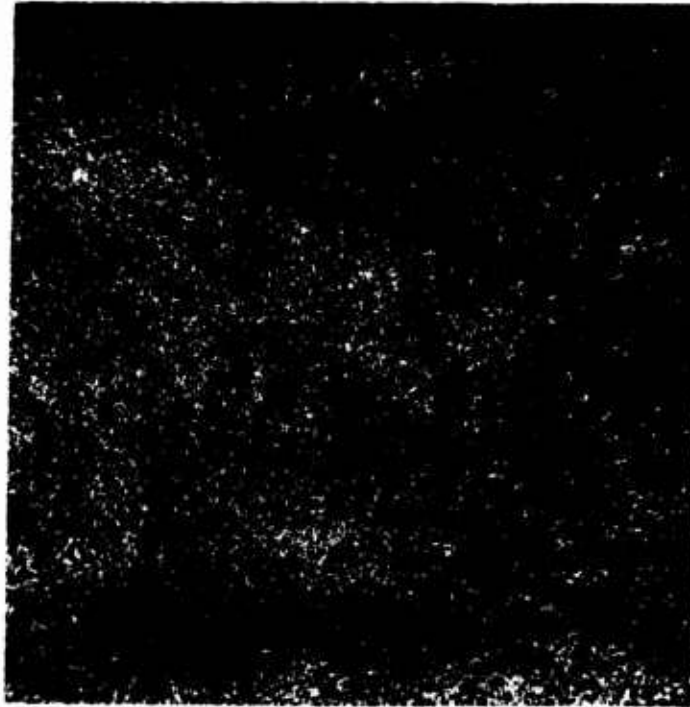


UNETCHED

X100

POROSITY PRESENT IN BROKEN TOOTH

**MICROSTRUCTURE OF TRANSVERSE SECTION OF
BROKEN TOOTH ON GEAR (SEE "A", FIGURE 2)**



PICRAL ETCH **X100**
TYPICAL NONMETALLIC STRINGERS IN BROKEN TOOTH



PICRAL ETCH
X1000
TYPICAL SLACK QUENCHED STRUCTURE OF BROKEN TOOTH
F - FERRITE,
B - TEMPERED HIGH TEMPERATURE BAINITE,
M - TEMPERED MARTENSITE

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